**Effect of Tillage and Water Management on Aggregate Stability of a Gleyic Cambisols**

*Abstract*

The objective of this study was to determine the effect of tillage and water management on the physical stability of irrigated lowland rice field, in Kwalkwalawa, Sokoto State. The experiment was carried out in a farmer`s field, near the Usmanu Danfodiyo University Teaching and Research Farm, Kwalkwalawa, Sokoto State. The coordinates of the area were taken using global positioning system (GPS) model Garmin etrex 20.0, which shows that the area is located on (N13$^0$05.963"E005$^0$12.650" and at 252m asl). The soils of the study area were classified as Aeric Endoaquepts at subgroup level in the USDA Soil Taxonomy System which correlated with Gleyic Cambisols in the World Reference Base. The treatments consisted of factorial combination of two tillage systems (conventional tillage (CT) and reduced tillage (RT), three irrigation water managements (Alternate one, two and three days irrigation intervals, which were carried out from one week after transplanting to hard dough stage) and three rice varieties (FARO 44, 60 and 61) all laid in a split plot design and replicated three times. After harvest, disturbed soil samples were collected with the aid of soil augar, prepared and passed through 5 mm sieve for aggregate stability determination. Result reveals that a consistent trend in aggregate size fraction was observed between the two tillage systems in both years, were a significant decrease in values of aggregate fractions of both the CT and RT in 2019 compared to in 2018. Aggregate size fraction of 5-2 mm had a significantly high value of RT compared to CT, 2-0.25 mm fractions were at par (0.41) while a greater value of aggregate fractions for CT in both 0.25-0.005 mm and <0.005 mm were observed compared to RT. Alternate days to irrigation and sampling depths increase with a corresponding in all the aggregate size classes in the two years of this study. A significant difference in MWD and GMD between the two tillage, water management and depth was noticed in both years of the trial where RT and alternate one day had high value while MWD and GMD increase with increasing depth.

Keywords: Tillage and Aggregate Stability.

**1.0 INTRODUCTION**

Soil aggregation is defined as the process whereby individual soil particles are joined into compound particles, clusters or aggregates (Sullivan, 2004). Aggregation is an important indicator for the soils` overall quality (Boix-fayos *et al*., 2001). It has potential benefits on soil moisture status, nutrients dynamics, tilth maintenance and erosion reduction (Kemper and Rosenau, 1986). The term aggregate stability is used by soil physicists to refer to the ability of the bonds of the aggregation to resist stress upon exposure (Rohoskova and Valla, 2004). In

determining the stability of soil aggregates, soil physicists generally subject samples of aggregates to artificially induced forces designed to simulate phenomena which are likely to occur in the field (Hillel, 1980). Resistance of soil solids to the mechanical abrasion rising from the two forces of destruction i.e water and air for long has been used to measure stability of aggregates. The technique for aggregate stability analysis is described by Kamper and Rosenau (1986). Dry sieving by White (1993) is the common method employed to simulate aggregate resistance to wind erosion.

Numerous factors affect stability of soils (Kay, 1997), most of which can be broadly grouped into two: endogenous and exogenous factors. The endogenous factors are those that are due to inherent soil properties. These factors include soil characteristics such as texture, clay mineralogy and nature of exchangeable cations, and quantity and quality of humus fractions (Lal and Shukla, 2004). The exogenous factors that affect soil aggregate stability include weather, biological processes, land use and management. Soil management or land use has been reported to influence soil aggregate stability (Six *et al*., 2000 and Castro *et al.,* 2002).

Pinheiro *et al*., (2004) found that soil surface aggregates of >2mm fractions formed (50%) soil under no-tillage compared with animal traction (35%) and conventional tillage (30%). He also observed that soil organic carbon (SOC) was higher under no-tillage than conventional tillage. Gajic *et al*. (2006) reported that conversion of forest to continuous cropping by conventional cultivation significantly decreased the stability of soil aggregates in the plough horizon. Also, Adesodun and Odejimi, (2010) reported that mean weight diameter (MWD) was significantly higher in un-cultivated land, whereas addition of compost to the cultivated land improved stability of the soil. It has been reported that soil organic matter and clay content are the main soil properties affecting soil aggregation, as they binds individual particles (Fryrear *et*

58 *al*., 1994 and Oliveira *et al.,* 2004). Any practices that reduce organic matter and disturbed clay

59 particles reduce soil aggregation.

60     This work was developed with the objectives of evaluating the aggregate size fractions,

61 MWD and GMD between the two tillage operations, water managements and depths.

## 62 2.0 MATERIALS and METHODS

### 63 2.1     Experimental Location

64     The experiment was conducted in a farmer`s field, near the Usmanu Danfodiyo

65 University Teaching and Research Farm, Kwalkwalawa, Sokoto State. The coordinates of the

66 area were taken using global positioning system (GPS) model Garmin etrex 20.0, which shows

67 that the area is located on latitude $13^005$`N and longitude $05^012$`E. The soils of the study area

68 were classified as Aeric Endoaquepts at subgroup level in the USDA Soil Taxonomy System

69 (USDA, 2014) which correlated with Gleyic Cambisols in the World Reference Base (FAO,

70 2015). The area experiences a long dry season from October to May and a short rainy season

71 from June to September. The dry season consists of a cold dry spell (Harmattan) roughly from

72 November to February, followed by a hot dry spell from March to May. The rainfall is erratic,

73 small in quantity and uneven distribution with peak in August and temperature fluctuates roughly

74 between $40^0$C maximum and $15^0$C minimum (Noma, 2005).

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### 77  2.2     Treatments and Experimental Design

78    The treatments consisted of factorial combination of two tillage systems (Conventional

79    tillage (CT); which involves cutting, inverting, puddling and leveling the field plots and reduced

80    tillage (RT); which involves puddling and leveling of the plots all with local hoes, shovels and

81    rakes), three water managements (Alternate one day, two days and three days irrigation intervals,

82    which were carried out from one week after transplanting to hard dough stage) and three rice

83    varieties; (FARO 44, 60 and 61).

84    The treatments were laid in a split plot design replicated three times. Tillage system was

85    allocated to the main plots, while water managements and varieties were allocated to the sub-

86    plots. Field observations and measurements were made for the two consecutive seasons using the

87    same experimental design and field layout. After each seasons harvest, disturbed soil samples

88    were collected with the aid of soil auger, prepared and passed through a 5mm sieve, while the

89    aggregate stability was determined by dry sieving methods as described by Van Bavel (1950) as

90    modified by Kemper and Rosenau (1986).Two hundred grams of bulk soil from the 5mm sieve

91    was weighed and transferred into nest of sieves consisting of diameters 2.0 mm, 0.25 mm and

92    0.005 mm. The nest of sieves was placed on a mechanical shaker and shaken for 2 minutes after

93    which the weight of soil retained in each sieve was determined.

94    Aggregate size distribution was calculated as the proportion of soil retained in each sieve as:

95    Aggregate size distribution $=\dfrac{Weight\ of\ soil\ retained\ in\ a\ sieve}{Total\ weight\ of\ soil\ taken}$

96    While the mean weight diameter (MWD) and geometric mean diameter (GMD) was calculated

97    as follows:

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99    $\text{MWD}_{dry} = \sum_{i=l}^{n} wixi$

100  $x_i$= The mean diameter of the class (mm)

101  $w_i$ = the proportion of each size class with respect to the total sample

102  $\text{GMD}_{dry} = \exp[\frac{\sum_{i=l}^{n} log xi}{\sum_{i=l}^{n} wi}]$

103  wi = weight of aggregate of each size class (g)

104  log xi = logarithm of the mean diameter of the size classes.

105  **2.3    Data Analysis**

106      Data generated were subjected to analysis of variance (ANOVA) using SAS 9.0 software,

107  (SAS, 2002). Significant means were compared using Duncan multiple range test (DMRT) at

108  P<0.05 (Gomez and Gomez, 1984).

109  **3.0    RESULTS and DISCUSSION**

110  **3.1    Effects of Tillage, Water Management and Depths on Aggregate Size Fractions in**
111  **2018**

112  From the result (Table 1), analysis of variance revealed a significant effect of tillage on

113  aggregate size fractions in all the separates, with CT having a significantly higher values, except

114  in 5-2 mm fractions, where RT have significant higher value compared to CT.

115  The results also shows a significant difference in all the aggregate size fractions with alternating

116  days of irrigations; with alternating one day irrigation having more of the aggregates size

117  fractions within all the separates while alternating three days irrigation having the least value

118  across all the separates.

119  However, sampling depth shows significant effects as they increased with depth. The observed

120  differences in the different aggregate separates between the two tillage and water management

121  may be as result of the degree of soil disturbances and the variation in timing of the water

122  application among the treatment combination, this made the CT with alternate one day irrigation

123  prone to ease of removal and being dislodged. Oades, (1984) observed that macro and micro

124  aggregates depends on organic matter for stability against destructive forces cause by quick

125  wetting. Aggregates were more disrupted in CT compare to RT according to Mrabet, (2002). The

126  decline in the size of the aggregates due to tillage could be credited to mechanical disruption of

127  macro aggregates which may have exposed soil organic matter previously protected against

128  oxidation. This is similar to the findings of Elijah (2016).

129  Significant interactions between the tillage and depth were noted among all the aggregate size

130  fractions across all the separates as depicted in Figure 1

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132  Table 1. Effects of tillage, water management and Depths on Aggregate size fractions in 2018

| Treatment | 5-2 mm | 2-0.25 mm | 0.25-0.005 mm | <0.005 mm |
|---|---|---|---|---|
| **Tillage (T)** | | | | |
| CT | 0.21b | 0.42a | 0.51a | 0.058a |
| RT | 0.22a | 0.41b | 0.48b | 0.048b |
| SE± | 0.0018 | 0.0044 | 0.0021 | 0.0020 |
| Water management (W) | | | | |
| Alternate one day (W1) | 0.22a | 0.42a | 0.50a | 0.059a |
| Alternate two days  (W2) | 0.21b | 0.42a | 0.49b | 0.053b |
| Alternate three days (W3) | 0.21b | 0.41b | 0.48c | 0.048c |
| SE± | 0.0022 | 0.0054 | 0.0024 | 0.0024 |
| Depth | | | | |
| 0-10 cm | 0.18b | 0.39b | 0.46b | 0.024b |
| 10-20 cm | 0.24a | 0.45a | 0.52a | 0.083 |
| SE± | 0.0018 | 0.0044 | 0.0021 | 0.0020 |
| Interaction | | | | |
| T × W | NS | NS | NS | NS |
| T × D | ** | ** | ** | ** |
| W × D | NS | NS | NS | NS |
| T × W × D | NS | NS | NS | NS |

133  Means followed by the same letter(s) within the same column are not significant at 0.05 level of
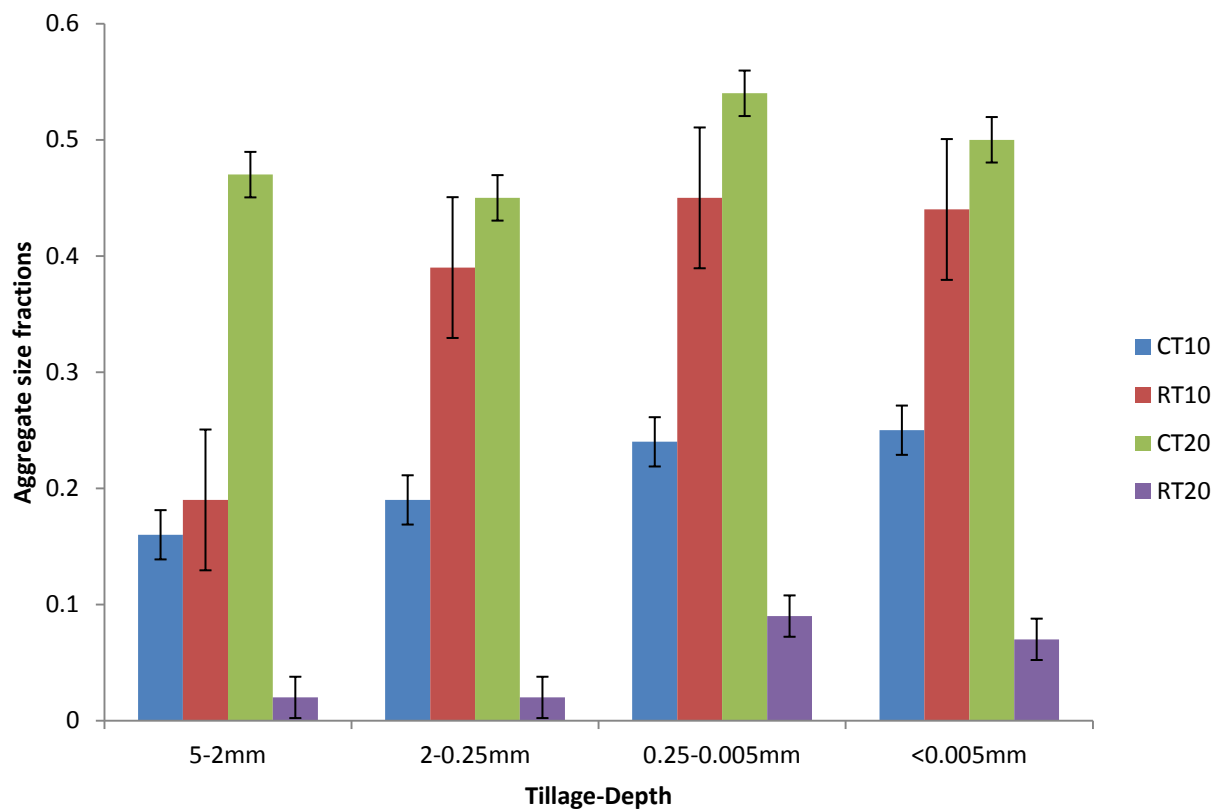134  probability, RT=Reduced tillage, CT= Conventional tillage, SE±=Standard error

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136  Fig.1: Interactions between tillage and depths on aggregate size fractions in 2018 (SE±
137  represented in bar)

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## 3.2 Effects of Tillage, Water Management and Depths on Aggregate Size Fractions in 2019

There was a significantly decreased in values of aggregates fractions of both the CT and RT in 2019. Table 2 reveals that aggregate size fraction of 5-2 mm had a significantly high value of RT compared to CT, 2-0.25 mm fraction were at par (0.41) while a similar trend of greater values of the remaining aggregate fractions for CT in both 0.25-0.005 mm and <0.005 mm were observed compared to RT.

Considering the alternating irrigation with the variation in all the aggregate size classes, one day alternate irrigation had the highest mean values among all the aggregate size classes among the separates while three days alternate irrigation is the least with the value (0.045) of alternate two days irrigation for <0.005 mm fraction being similar with (0.047) of alternate three days irrigation for the same aggregate.

Similar trend was also observed in the sampling depths as in 2018, with a significant effect as they increased with depth. Significant interaction between the tillage and depth was observed among all the aggregate fractions in 2019 except on <0.005 mm aggregate fraction which shows no significant interaction. This consistent trend in the variation of all the aggregates may be as a result of the degree of disruption of all the aggregates fractions both in CT and RT, with CT been more pronounced in the second year due to continuous disturbance of those soil without subsequent addition of organic matter that will boost the bond strength of those soils. Enjugu (2014) and Elijah (2016) also observed a steady increase in aggregate size fraction over a two year tillage research in Samaru.

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173 Table 2. Effects of tillage, water management and Depths on Aggregate size fractions in 2019

| Treatment | 5-2 mm | 2-0.25 mm | 0.25-0.005 mm | <0.005 mm |
|---|---|---|---|---|
| **Tillage (T)** | | | | |
| CT | 0.20b | 0.41 | 0.50a | 0.055a |
| RT | 0.21a | 0.41 | 0.47b | 0.043b |
| SE± | 0.0021 | 0.0050 | 0.0026 | 0.0025 |
| Water management (W) | | | | |
| Alternate one day (W1) | 0.21a | 0.42a | 0.49a | 0.055a |
| Alternate two days (W2) | 0.21a | 0.41b | 0.49a | 0.045b |
| Alternate three days (W3) | 0.20b | 0.40c | 0.48b | 0.047ab |
| SE± | 0.0026 | 0.0062 | 0.0032 | 0.0034 |
| Depth | | | | |
| 0-10 cm | 0.18b | 0.38b | 0.45b | 0.022b |
| 10-20 cm | 0.24a | 0.44a | 0.52a | 0.077a |
| SE± | 0.0021 | 0.0050 | 0.0026 | 0.0025 |
| Interaction | | | | |
| T × W | NS | NS | NS | NS |
| T × D | ** | ** | ** | NS |
| W × D | NS | NS | NS | NS |
| T × W × D | NS | NS | NS | NS |

174 Means followed by the same letter(s) within the same column are not significant at 0.05 level of
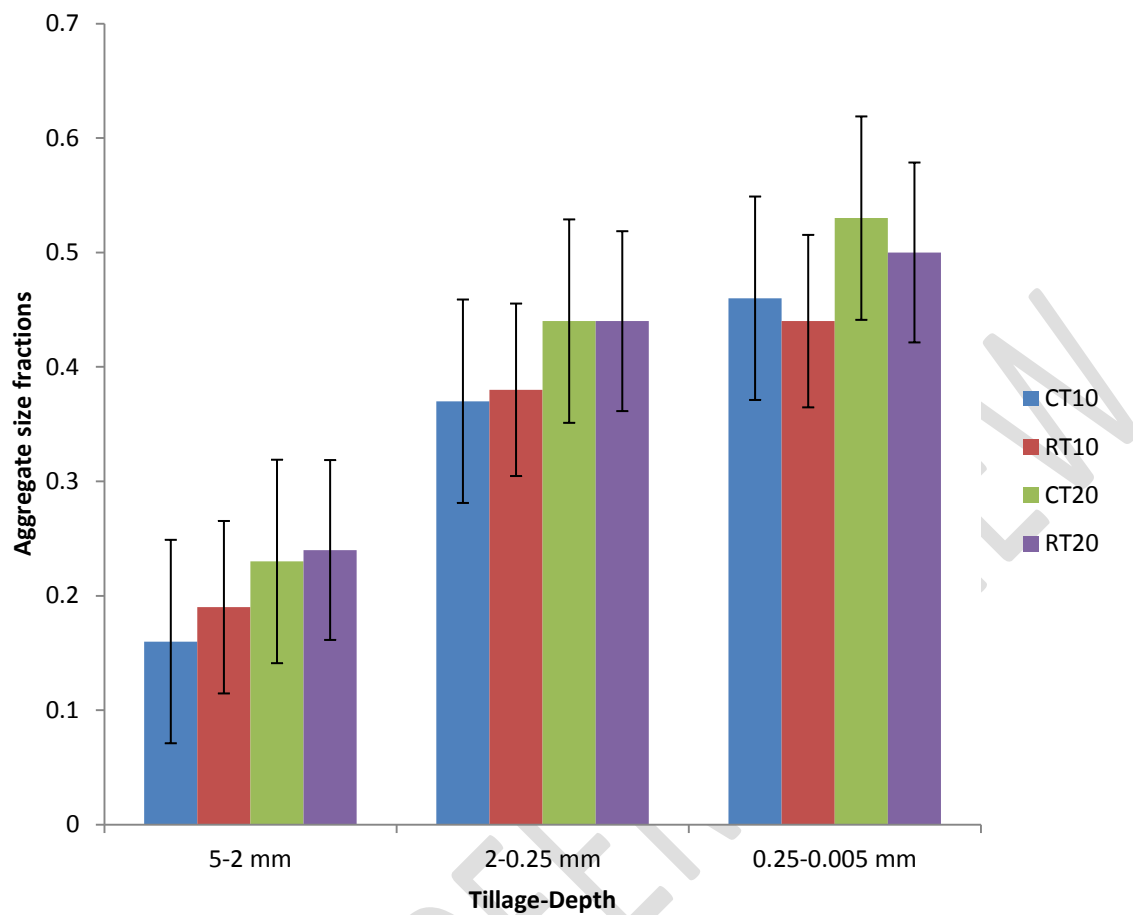175 probability, RT=Reduced tillage, CT= Conventional tillage, SE±=Standard error

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Fig. 2: Interactions between tillage and depths on aggregate size fractions in 2019 (SE±
represented in bar)

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**3.3 Effects of Tillage, Water Management and Depths on MWD and GMD of Aggregate in 2018 and 2019**

The mean weight diameter (MWD) and geometric mean diameter (GMD) were significantly affected by tillage (Table 3) in the two years of this study. In 2018, a significant difference was noticed in tillage with RT shows significantly higher value for MWD and GMD. The alternating days to irrigation also shows a significant increase in values of both the MWD and GMD, where alternate one day irrigation records the highest value while alternate three days irrigation had the least.

Significant increase in MWD and GMD across the two depth increase with increasing depth in 2018, and there was significant interaction between tillage and depth among the MWD and GMD of the aggregate in 2018 (Fig. 3)

A similar trend in MWD and GMD were also observed in 2019 (Table 3). This trend shows a gradual decrease in the value of both MWD and GMD for the two tillage systems across the two years. This shows the decrease of the stability of the soil to various tillage operations. Unger, (1991) reported that an increase in MWD and GMD is its ability to withstand erosion. The MWD and GMD increased as the depth of sampling increases indicating that the deeper the soil, the less vulnerable the soil will be exposed to erosion. Oguike and Mbagwu, (2009) observed that tillage with traditional hoeing and clean weeding together with reduced organic matter content, as in the case of this trial field may explain the low value of MWD and GMD observed under CT compared to the RT tillage practices. Fuents *et al*. (2011) and Enjugu (2014) also reported that soil with conventional tillage plus reduced organic matter had a low MWD and GMD compared to soil with no-tillage plus residue, which indicates that despite the incorporation of residues, there was a negative effect on soil stability with tillage.

219 The variation of MWD and GMD and soil depth could be probably due to reduced soil

220 disturbance, redistribution of residues and homogenization effect of plowing (Tan *et al.*, 2004)

221 Table 3 Effects of tillage, water management and Depth on Mean Weight Diameter and
222 Geometric Mean Diameter in 2018 and 2019

| Treatment | 2018 | | 2019 | |
|---|---|---|---|---|
| | MWD | GMD | MWD | GMD |
| **Tillage (T)** | | | | |
| CT | 1.09b | 0.80 | 1.08b | 0.79b |
| RT | 1.15 | 0.82 | 1.14a | 0.81a |
| SE± | 0.0011 | 0.0083 | 0.0011 | 0.0027 |
| Water management (W) | | | | |
| Alternate one day (W1) | 1.13a | 0.82a | 1.12a | 0.81a |
| Alternate two days (W2) | 1.12b | 0.81b | 1.11b | 0.80b |
| Alternate three days (W3) | 1.11c | 0.80c | 1.11b | 0.80b |
| SE± | 0.0013 | 0.0010 | 0.0013 | 0.0033 |
| Depth | | | | |
| 0-10 cm | 1.09b | 0.78b | 1.08b | 0.77b |
| 10-20 cm | 1.15a | 0.84a | 1.15a | 0.83a |
| SE± | 0.0011 | 0.0083 | 0.0011 | 0.0027 |
| Interaction | | | | |
| T × W | NS | NS | NS | NS |
| T × D | ** | ** | ** | ** |
| W × D | NS | NS | NS | NS |
| T × W × D | NS | NS | NS | NS |

223 Means followed by the same letter(s) within the same column are not significant at 0.05 level of
224 probability, RT=Reduced tillage, CT= Conventional tillage, SE±=Standard error
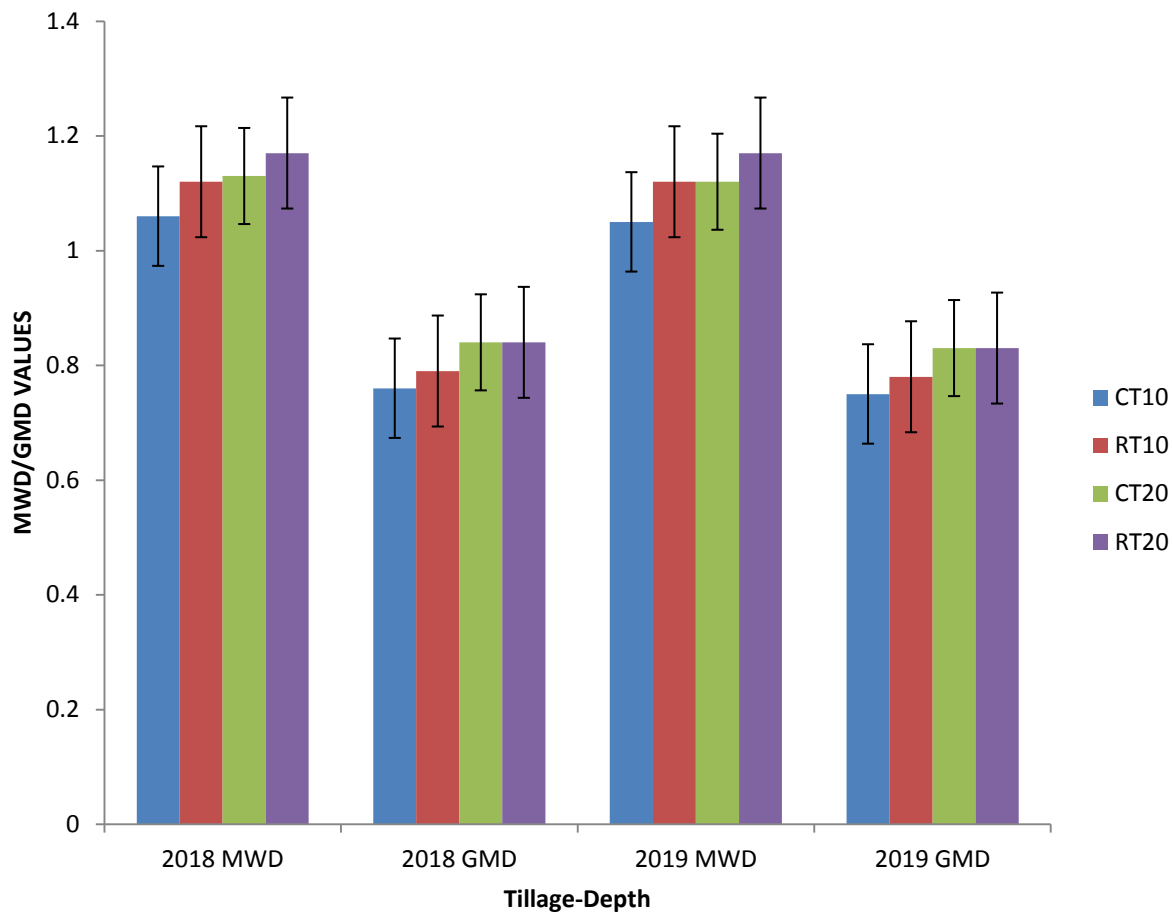
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Fig. 3: Interactions between tillage and depths on MWD and GMD in both 2018 and 2019 (SE±
represented in bar).

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## 4.0 CONCLUSION

The use of tillage implements interferes with the stability of the soil aggregate, where
reduced tillage have higher MWD and GMD compared to conventional tillage.

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**REFERENCES**

Adesodun, J.K. and Odejimi, O.E. (2010). Carbon-nitrogen sequestration potentials and structural stability of a tropical Alfisol as influenced by pig-composted manure. *International Agrophysics,* **24**:333-338.

Boix-fayos, C., Calvo-cases, A., Imeson, A.C. and Soriano-sato, M.D. (2001). Influence of soil properties on the aggregation of some Mediterranean soils and the use of aggregate size and stability as land degradation indicators. *Catena*, **44**: 47-67.

Castro Filho, C., Lourenco, A ., Guimaraes, M.F., Fonseca, I.C.B. (2002). Aggregate stability under different soil management systems in a Red Latosol in the sate of Paraná, Brazil. *Soil and Tillage Research*, **65**:45-51

Elijah, O.O. (2016). Contribution of conservation agriculture to improvement of soil quality and maize (*Zea mays* L.) yield in Samaru, Northern Guinea Savanna of Nigeria. An unpublished M.Sc thesis, submitted to the Department of Soil Science, Ahmadu Bello University, Zaria.

Enjugu, A.M. (2014). Effect of tillage practices on soil carbon stock, hydro-physical properties and yield of maize in a Northern Guinea Savanna alfisol. An unpublished M.Sc thesis, submitted to the Department of Soil Science, Ahmadu Bello University, Zaria.

FAO (2015). World Reference Base for Soil Resources 2015. International Soil Classification System for Naming Soil and Creating Legends for Soil Maps.

Fryrear, D.W., Krammes , C.A., Williamson, C.M. and Zobeck, T.M. (1994). Computing the wind erodible fraction of soils. *Journal of Soil and Water Conservation*, **49**:183-188.

Fuents, M., Claudia H., Jorge, E., Fernando, D.L., Armando, g., Luc, d., Nele, V., and Bram, G. (2011). Conservation agriculture increased organic carbon in the top soil macro-aggregates and reduced soil $CO_2$ emmisions. *Plant soil.*

Gajic, B., Dugalic, G. and Djurovic, N. (2006). Comparison of soil organic matter content, aggregate composition and water stability of Gleyic Fluvisol from adjacent forest and cultivated areas. *Agronomy Research,* **4(2)**:499-508.

Gomez, K.A. and Gomez, A.A. (1984) *Statistical Procedures for Agricultural Research,* Wiley Inter-science, New York, NY. 704 pp

Hillel, D. (1980). *Fundamental of Soil Physics*. Academic Press, Inc. New York. 109pp.

Kay, B.D. (1997). Rates of change in soil structure under difficult cropping systems. *Advance Soil Science*, **12**:1-52.

Kember, W.D. and Rosenau, R,C. (1986). Aggregate stability and size distribution. In: *Methods of Soil Analysis.* Part 1, 2$^{nd}$ Ed. A. Klute (Ed.). Agronomy monograph. ASA and SSSA, Madison, WI, 425-442pp.

Lal, R. and Shukla, M.K. (2004). *Principles of Soil Physics*. Marcel Dekker, Inc. 18, 377pp.

275 Mrabet, R. (2002). Stratification of soil aggregation and organic matter under conservation
276 tillage systems in Africa. *Soil and Tillage Research* **66**:119-128.
277 Noma, S.S. (2005). Properties, genesis and classification of soils of Sokoto-Rima floodplains at
278 Sokoto, Nigeria. An unpublished Ph.D thesis, submitted to the Department of Soil
279 Science and Agricultural Engineering, Usmanu Danfodiyo University, Sokoto.

280 Oades, J.M., (1984). Soil organic matter band structural stability: mechanisms and implications
281 for management. *Plant soil*, **76**:319-337.
282 Oguike P.C.and Mbagwu J.S.C (2009) Variations in Some Physical Properties and Organic
283 Matter Content of Soils of Coastal Plain Sand under Different Land Use Types. *World*
284 *Journalof Agricultural Sciences* **5** (1): 63-69, 2009 ISSN 1817-3047.
285 Oliveira, G.C., Dias. Junior., M.S., Resckn, D.V.S. and Curi, N.(2004). Chemical and physical-
286 water characterization of a Red Latosol after twenty years of soil management and
287 cultivation. *Brazilian Journal of Soil Science*, .**28**:327-336

288 Pinheiro, E.F.M., Pereira M.G.and Anjos. L.H.C. (2004). Aggregate distribution and soil organic
289 matter under different tillage systems for vegetable crops in a Red Latosol from Brazil.
290 *Soil and Tillage Research,* **77**:79–84.
291 Rohoskova, M. and Valla, M. (2004). Comparison of two methods for aggregate stability
292 measurement-a review. *Plant, Soil Environment*, **50**:379-382.

293 SAS. (2002) Proprietary Software Version 9.0. SAS Institute Inc, Cary, NC, USA.

294 Six, J., Elliot, E.T., and Paustian. K. (2000). Soil macro aggregate turnover and micro aggregate
295 formation: a mechanism for C sequestration under no tillage agriculture. *Soil and*
296 *Biochemistry*, **32**:2099-2103.
297 Sullivan, P. (2004). Sustainable Soil Management. ATTRA (National Sustainable Agricultural
298 Information Service). Publication. #1P027/33, ATTRA, Fayetteville, USA. Access
299 3/4/2018.
300 Tan, Z. X., Lal, R., Izaurralde, R. C and Post, W. M. (2004). Biochemically proctected soil
301 organic carbon at the North Applachian experiment water shed. *Soil Science Society of*
302 *American journal* **9**: 1-10.
303 Unger, P.W. (1991). Overwinter changes in physical properties of no-tillage soil. *Soil Science*
304 *Society of America Journal*, **55**:778-782pp.

305 USDA- United States Department of Agriculture. (2014). Soil survey staff: Keys to soil
306 taxonomy (12th ed…) Washington DC; USDA Natural Resources Conservation Service.

307 Van Bavel, C.H.M. (1950). Mean weight diameter of soil aggregates as a statistical index
308 of aggregation. *Soil Science of American Proceedings,* **14**:20-23.

309 White, W.M. (1993). Dry aggregate distribution. In M.R. Carter (Ed.) "*Soil Sampling and*
310 *Methods of Analysis*". Lewis Publishers, Boca Raton, FL, 659-662pp.

311